Report as of FY2008 for 2008PA87B: "Controls on nitrogen and phosphorous transport and fate in northern Appalachian streams"

Publications

- Conference Proceedings:
  - Kerr, PC, and MN Gooseff. 2008.Comparison of model structure in multiple-transient storage modeling of solute transport in streams: Nested versus competing storage zones. American Geophysical Union Fall Meeting, San Francisco (H11B).
  - Gooseff, MN, MA Briggs, PC Kerr, MR Weaver, W Wollheim, BJ Peterson, K Morkeski, and CS Hopkinson. 2009. Separating in-channel and hyporheic transient storage processes in river networks - A path toward improved quantification of stream-groundwater interactions. Joint Assembly of the American Geophysical Union (H71D-02).

Report Follows

PRINCIPAL FINDINGS AND SIGNIFICANCE

In this project, we conducted repeated whole stream nutrient additions of NO_3 and PO_4, each individually and a third addition of the two combined (NO_3 + PO_4) to determine whether the presence of both nutrients would enhance uptake of one or the other (in all addition experiments NaCl was also added as a conservative tracer). We expected that the elevated presence of both nutrients would result in less potential for limitation or saturation of one nutrient or the other (i.e., as might be expected in single-nutrient addition experiments). We performed 5 'sets' of these 3 addition types in three small streams in central Pennsylvania (Table 1).

Table 1. Details of sites, conditions, and addition experiments.

Experiment	Date	Addition	Q (L/s)	Reach length (m)
Benner Run 1	06/15/08	NO_3	110	340
Benner Run 1	06/16/08	PO_4	110	340
Benner Run 1	06/17/08	NO_3+PO_4	110	340
Benner Run 2	07/14/08	NO_3	57	460
Benner Run 2	07/15/08	PO_4	57	460
Benner Run 2	07/17/08	NO_3+PO_4	57	460
Laurel Run 1	06/24/08	NO_3	70	460
Laurel Run 1	06/25/08	PO_4	70	460
Laurel Run 1	06/26/08	NO_3+PO_4	70	460
Laurel Run 2	07/21/08	NO_3	30	460
Laurel Run 2	07/22/08	PO_4	30	460
Laurel Run 2	07/23/08	NO_3+PO_4	30	460
Leading Ridge 1	08/09/08	NO_3	0.25	200
Leading Ridge 1	08/11/08	PO_4	0.25	200
Leading Ridge 1	08/14/08	NO_3+PO_4	0.25	200

Our analysis of computed uptake lengths (S_W – the average distance a nutrient molecule travels downstream before being taken up) suggests that, on average, NO_3 uptake is enhanced by the presence of elevated concentrations of PO_4. The average NO_3 S_W during NO_3-only injections was 32,567 m, whereas during the coupled NO_3+PO_4 additions, the average S_W for NO_3 was 14,077 m. However, both sets of NO_3 S_W data are quite variable, ranging from -5000m to 142,857m for NO_3-only injections and from -50,000 m to 50,000 m in coupled additions (Figure 1A).

Our analysis of computed S_W values for PO_4 suggests that, on average, there is little to no effect from the presence of elevated NO_3 concentrations. The average of PO_4 S_W during PO_4-only injections was 4,800 m, whereas during the coupled NO_3+PO_4 additions, the average S_W for PO_4 was 4,857 m. There is less variability in PO_4 S_W data, compared to NO_3 S_W data, ranging from -5000m to 25,000m for PO_4-only injections and from 44 m to 10,000 m in coupled additions (Figure 1B). It is interesting to note that during coupled additions, all PO_4 S_W values were greater than 0.

Accounting for stream flow velocity, we can compare nutrient uptake velocities (v_f = (u*d)/S_W, where u is stream flow velocity and d is average depth). For NO_3, this analysis suggests a reduced demand, on average, during coupled additions (1.16×10^{-5} m/s) compared to during NO_3-only additions (8.10×10^{-5} m/s). Uptake velocity values for NO_3 ranged from -3.3×10^{-5} to 3.14×10^{-4} m/s for NO_3-only additions and from -7.6×10^{-5} to 6.98×10^{-5} m/s for coupled additions (Figure 1C). The opposite interpretation comes from the analysis of PO_4 uptake lengths, which average 9.27×10^{-4} m/s for PO_4-only additions and 1.05×10^{-3} for coupled additions. This comparison of greater PO_4 demand in coupled additions is evident in 4 of the 5 addition experiments (Figure 1D).

The goal of this research project was to determine whether the interpretation of single nutrient addition experiments was likely to be modified significantly by co-addition of another typically limiting nutrient. Our results indicate that 1) uptake lengths are long and nutrient demand is fairly small in these streams, compared to values published in other temperate, forested catchment streams, and 2) there is not a consistent trend of increased NO_3 or PO_4 uptake during additions of both nutrients compared to the addition of each alone. Whereas these streams represent only a single stream type, the findings are significant in suggesting that single nutrient addition experiments are useful in characterizing the dynamics of that individual nutrient. Furthermore, the stoichiometry of uptake, beyond background ratios does not appear to dramatically influence nutrient demand. Given the challenges faced by resource managers as society deals with increased nutrient loading to streams and ultimately coastal areas, the findings from this research suggest that co-additions of nutrients as a means of exploring nutrient uptake dynamics is not likely to provide new breakthroughs. However, using the standard methods here, it was not possible to determine whether full cycling of N or P had been completed during the addition experiments. That is, we could not determine separately rates of uptake and production separately. Hence, it may be possible with the inclusion of isotopic tracers of NO_3 or PO_4 to further evaluate specific rates of N or P processing.

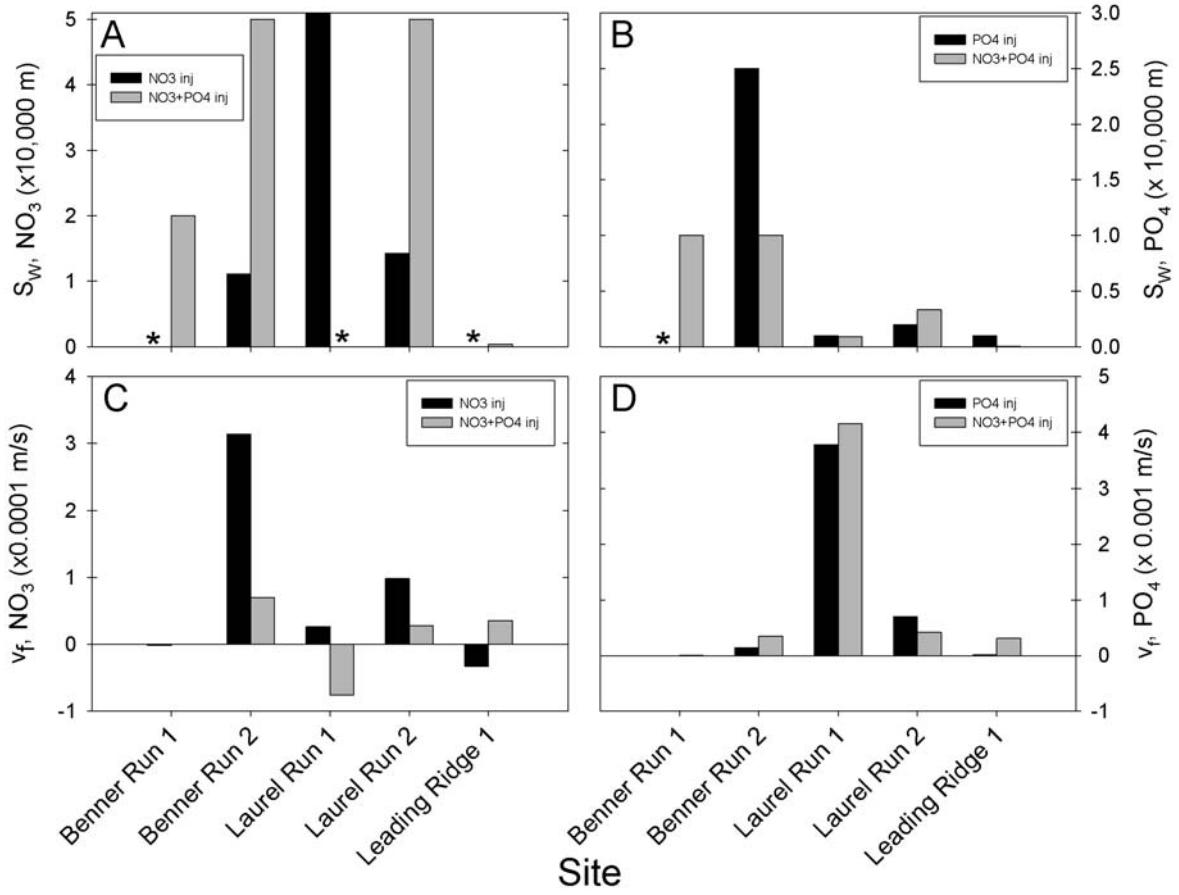

Figure 1. Summary results from 5 sets of whole stream nutrient addition experiments comparing A) nitrate (NO_3) and B) phosphate (PO_4) uptake lengths (S_W) and C) nitrate and D) phosphate uptake velocities (v_f) in nitrate-only and nitrate+phosphate addition experiments. * indicates that uptake lengths were negative (i.e., nutrient was indicated to be produced rather than taken up) over the reach length of interest. See Table 1 for addition experiment details. Note in panel A, the uptake length for Laurel Run 1 during the NO_3-only addition is 142,857 m.